Farmers' Impatience and Fertilizer Use in Burkina Faso

T. Le Cotty* E. Maître d'Hôtel† R. Soubeyran‡ J. Subervie§

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Abstract

This paper investigates the reasons why African farmers who face similar financial constraints, market environments and agro-ecological conditions differ in their chemical fertilizer use behaviors. We analyze the influence of individual preferences on fertilizer use. We model the fertilizer investment decision of a farmer : the model predicts that the quantity of fertilizer used is an increasing function of discounting. We then empirically test the empirical relevance of such a model, building upon an agricultural survey that we conducted on 1277 maize producers in the Mouhoun and Tuy provinces of Burkina Faso and upon an field experiment we led to elicit their risk aversion and discounting. Controlling for individual financial constraints and access to fertilizer, we show that experimental choices about time preferences correlate with observed fertilizer use behavior. This paper presents one of the the first field evidence that links hypothetical time discount questions to observed agricultural decisions.

Key words: fertilizer, discounting, risk aversion, Africa
JEL: Q13, Q12, Q16, Q18

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*CIRAD, UMR 8568 CIRED, F-34398 Montpellier - France

†CIRAD, UMR 1110 MOISA, F-34398 Montpellier - France. Email: elodie.maitredhotel@cirad.fr

‡INRA, UMR 1135 LAMETA, F-34000 Montpellier - France

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1 Introduction

In the last forty years, cereals yields rose significantly in most developing countries, but Sub-Saharan Africa has not participated to such an agricultural success (World Bank, 2008). Yields have reached an average of five tons per hectare in Eastern Asia while they maintain themselves around one ton per hectare in Sub-Saharan Africa (FAOSTAT data). It is commonly admitted that rising yields have been driven by the widespread use of irrigation, improved varieties and fertilizer use and that the low use of fertilizers is responsible for the observed stagnation of yields in Africa (Morris, Kelly, Kopicki, and Byerlee, 2007). Indeed, the average intensity of fertilizer use is less than 10 kilograms per hectare of cultivated land in Sub-Saharan Africa, while it is above 250 kilograms per hectare of land in Eastern Asia (FAOSTAT data). Agronomic experimentations led in Sub-Saharan African countries established a strong yield gap between observed yields in the field and measured yields in the stations, this gap being explained by the low use of chemical fertilizers by farmers (Lobell, Cassman, and Field, 2009). This paper seeks to understand why African farmers do not use more fertilizers to gain higher yields.

There is an extensive literature on agricultural technology adoption in developing countries that seeks to understand why farmers in some countries are reluctant to adopt innovations while farmers in other countries are not. Regarding the low adoption of chemical fertilizers in Africa, the most commonly advanced reasons are related to both demand-side and supply-side factors. Demand for fertilizer can be hindered either because of high fertilizer prices, or low ability of farmers to raise the resources needed to purchase fertilizer (Binswanger and Sillers, 1983; Ramaswani, 1992; Duflo et al., 2011). On the supply side, fertilizer distribution may be discouraged by an unfavorable business climate characterized by a small market size, high transportation costs and high cost of financing (Morris, Kelly, Kopicki, and Byerlee, 2007). Moreover, the fact that farmers facing similar financial constraints, market environments and agro-ecological conditions differ in fertilizer purchasing behavior suggests that differences in agricultural decisions may also be explained by individual preferences. This paper investigates the importance of risk and time preferences in agricultural behavior focusing on fertilizer use.

Behavioral considerations that may hinder fertilizer use have been recently highlighted in the literature on technology adoption, borrowing elements from laboratory experiments and behavioral economics (Fafchamps 2010). Those behavioral patterns may be related to risk aversion (Sandmo, 1971; Binswanger and Sillers, 1983) and impatience (Duflo, Kremer, and Robinson, 2011). Risk aversion is often mentioned as a potentially important contributing factor to under-investment in farming systems (Sandmo, 1971).

The risk may be inherent to the technology itself, as it is the case in chemical fertilizers where the use of fertilizer may increase variance of yields and variance of incomes net of fertilizer costs (Just and Pope 1979; Roumasset, Rosegrant et al. 1989; Fafchamps 2010). Thus, if we consider a rational but risk adverse farmer, it is expected that more risk adverse farmers will reduce their use of fertilizers. Binswanger was the first author to build upon experimental economics to elicit individual risk aversion and to try to explain the low use of input among farmers (Binswanger, 1980). He compared the elicited levels of risk aversion obtained in India (Binswanger, 1980) to those obtained through similar experiments in the Philippines (Sillers 1980), El Salvador (Walker 1980) and Thailand (Grisley 1980) and established that risk aversion levels were very close from one country to one another and thus that risk aversion had a only limited power for explaining differential investment behaviour (Binswanger and Sillers, 1983). More recently, authors have developed the idea that we should consider time preferences to better understand the low use of fertilizers (Fafchamps, 2010; Duflo, Kremer, and Robinson, 2011). Impatient farmers are expected to use less quantities of fertilizers because they value higher a good at an earlier date than at a later date. Applying fertilizers at the beginning of the crop season and having to expect the harvest to have a return to investment or buying fertilizer after harvest when there are no liquidity constraints to apply this fertilizer later, may not be rational to impatient farmers. Besides being impatient, farmers may have present biased preferences, meaning that they are more impatient with choices affecting current consumption than with choices affecting future consumption. In Kenya, it has been highlighted that farmers may plan to buy fertilizers but postpone the purchase of fertilizer to a later period where they may be unable to do so because of "procrastination" (Duflo, Kremer, and Robinson, 2011). Extremely impatient farmers are expected not to purchase any unit of fertilizers, while moderately impatient farmers may purchase or not fertilizers : - Farmers who are moderately impatient with about the same level of impatience now and in the future are expected to purchase fertilizers : their individual preferences are time consistent - Farmers who are more impatient with choices affecting consumption in the present than with choices that will play in the future may consume too much and be unable to buy fertilizers in the future : their individual preferences are time inconsistent. Thus the relation between impatience and fertilizers use is twofold : impatient farmers are expected to use less quantities of fertilizers and impatient farmers with present biased preferences are expected to use lesser quantities of fertilizers. Despite those stimulating proposals, the effect of time preferences on fertilizers use has not been

empirically tested in the economic literature [1].
The contribution of this paper is to empirically investigate the relative influence of risk and time individual preferences on fertilizer use, drawing upon an agricultural survey and an experiment led in Burkina Faso. Standard practice in inter-temporal welfare analyses is to assume that risk and time preferences are the same across farmers when one would expect a priori that subjective time preferences differ across different individuals (Harrison, Humphrey, and Verschoor, 2010). We build upon very recent papers from the field experiment literature that aim at eliciting risk aversion coefficients and discount rates for individuals (Harrison, Lau, and Williams, 2002; Andersen, Harrison, Lau, and Rutstrom, 2008) and we relate farmers elicited preferences to their behaviors, captured trough an original agricultural survey. There is a long tradition in development economics of collecting original data on agricultural behavior in order to test a specific economic hypothesis (Duflo, 2006). Recently, this literature based on agricultural surveys has merged with an expertise in setting up field experiments in order to elicit farmers' individual preferences in developing countries. To date however, very few papers were able to show that experimental choices correlate with observed agricultural behavior. Yet, understanding such relationship - if there is any - is of importance for development because it would help designing relevant development policies. Typically, very impatient people may be reluctant to use development tools like saving products or microcredit innovations.

A small number of studies aim to determine to what extent individual preferences drive behaviors in developing countries. Liu and Huang (2013) established that risk aversion -elicited trough an experiment led on 320 Chinese farmers- has an increasing effect on the use of pesticides. Besides this study on risk aversion, most of those studies that relate individual preferences to behaviors tend to focus on the relation between present-biased preferences and the adoption of saving or credit innovations provided through randomized control trials. Ashraf, Karlan, and Yin (2006) asked hypothetical time discounting questions to 1777 clients of a Philippine bank and show that women who exhibited present-biased preferences were indeed significantly more likely to open

[1] We found however three recent empirical studies dealing with the influence of time preferences upon behaviors (not related to fertilizers use) that build upon both experiments and surveys. In India, an experiment led on farmers established that farmers who had present biased preferences were more keen to borrow money from micro-credit institutions (Bauer, Chytilová et al. 2012). This result is consistent with similar results established in the context of USA where present biased preferences had an increasing effect on credit card borrowing (Meier and Sprenger, 2010). Similarly, in the Philippines, it was established that people with present biased preferences were more reluctant to take up forced saving contracts (Ashraf, Karlan et al. 2006)

a savings account with restrict access. On the same line, Bauer, Chytilova, and Morduch (2012) show from a random sample of 573 Indian villagers that, among women who borrow, those with present-biased preferences are particularly likely to be microcredit borrowers. Recently, Dupas and Robinson (2013) use data from a field experiment in Kenya in order to show that providing individuals with simple informal savings technologies can substantially increase investment in preventative health. Their results moreover indicate that women who exhibit present-biased preferences do not benefit from saving product with easily access to the money while they do benefit from the combination of the stronger commitment to make regular contributions and credit provided by a group setting (in this case, a Rotating Savings and Credit Association). All of these studies conjecture from their results that time-inconsistency might be an important constraint for saving, whether at home or in a "self-help group" with microcredit purpose. In particular, they suggest that if the present-biased individuals are sophisticated enough, they will opt for commitment-saving mechanisms that allow them to save according to their future plans and keep them from giving in to their immediate temptations.

This paper contributes to the literature that aims to highlight a link between elicited individual preferences and observed agricultural decisions in several ways. First, we focus on fertilizer use for crop production, while most previous studies have focused on credit and saving products. Second, contrary to Ashraf, Karlan, and Yin (2006) and Dupas and Robinson (2013) who study the impact of individual preferences on the participation to a development program, we rather study current agricultural behavior of farmers. Third, we provide evidence that a time-consistent model of discounting can explain variability in fertilizer use. Duflo, Kremer, and Robinson (2011) argue that even when facing small fixed costs of purchasing fertilizer, farmers may postpone fertilizer purchases until later periods. When they have inconsistent time preferences, those farmers end up being impatient in the last period in which buying is possible and finally fail to invest in fertilizer. We argue that even in cases when farmers are not financially constrained and benefit from facilitated access to fertilizer, we can establish a causal link between the discount rate and fertilizer use in a framework where farmers are time-consistent.

In the next section we model fertilizer investment decisions of a farmer who displays time consistent preferences. The model predicts that the quantity of fertilizer used is an increasing function of the discount rate and independent of risk aversion. Section 3 describes the sample, the experimental design for eliciting discount rates, risk aversion coefficients and the survey data. Section 4 shows how the experimental choices correlate with observed fertilizer use behavior and Section 5 concludes.

2 A Model of Fertilizer Use

2.1 No uncertainty

We consider the inter-temporal decision of a farmer who produces maize. A typical year is divided into two periods: the harvest season and the lean season. At the harvest season, the farmer gets its production f_t, consumes $f_t - s_t \geq 0$ and keeps s_t up to the lean season. At the harvest season, the price of cereals is $\underline{p}$. There is thus no uncertainty on crop prices nor on harvest levels. This assumption is left aside later.

At the lean season, the farmer buys (and uses) a quantity x_t of fertilizers at unit price b. He consumes the remaining value of his harvest, $\overline{p}s_t - wx_t \geq 0$, where $\overline{p}$ is the price of cereals at the lean season. The production f_t increases with the quantity of fertilizers used, x_{t-1}. Formally, $f_t \equiv f(x_{t-1})$ and $f' > 0$ (we also assume $f'' \leq 0$). In our framework, the farmer has no access to credit and cannot store any valuable goods between the lean season and the next harvest season, meaning that the whole harvested quantity is supposed to be self-consumed or sold before the next harvest season.

The price of cereals usually increase from the harvest season to the lean season, and then we assume that $\overline{p} > \underline{p}$. Let u denotes the utility function of the farmer (with $u' > 0$ and $u'' \leq 0$) and $\sqrt{\rho}$ denotes the discount factor between two seasons (from harvest to lean or from lean to harvest). Starting from the harvest season of year t, the discounted sum of utility of the farmer is given by

$$U_t = \sum_{d=t}^{+\infty} \rho^{\frac{d-t}{2}} u\left(\underline{p}\left(f\left(x_{d-1}\right) - s_d\right)\right) + \rho^{\frac{d-t+1}{2}} u\left(\overline{p}s_d - bx_d\right)$$

The farmer chooses the quantities of fertilizer, x_t, and the stocks, s_t, for all t, that maximizes his discounted sum of utility.

The necessary conditions for an interior solution ($x_t > 0$, $s_t > 0$, $f_t - s_t > 0$, $\overline{p}s_t - wx_t > 0$) are:

$$-\underline{p}u'\left(\underline{p}\left(f\left(x_{t-1}\right) - s_t\right)\right) + \overline{p}\sqrt{\rho}u'\left(\overline{p}s_t - bx_t\right) = 0,$$

and,

$$-bu'\left(\overline{p}s_t - bx_t\right) + \underline{p}f'\left(x_t\right)\sqrt{\rho}u'\left(\underline{p}\left(f\left(x_t\right) - s_{t+1}\right)\right) = 0.$$

Let us focus on the stationary solution, i.e. $x_t = x$ and $s_t = s$. The necessary conditions become:

$$\frac{u'\left(\overline{p}s - bx\right)}{\underline{p}u'\left(\underline{p}\left(f\left(x\right) - s\right)\right)} = \frac{1}{\sqrt{\rho}\overline{p}},$$

and,

$$\frac{\sqrt{\rho}f'\left(x\right)}{b} = \frac{u'\left(\overline{p}s - bx\right)}{\underline{p}u'\left(\underline{p}\left(f\left(x\right) - s\right)\right)}$$

Hence, we must have

$$f'\left(x\right) = \frac{b}{\rho\overline{p}}$$

or,

$$x = f'^{-1}\left(\frac{b}{\rho\overline{p}}\right)$$

The model thus shows that the quantity of fertilizers:

- is a decreasing function of the price of fertilizers, b.
- is an increasing function of the annual discount factor (patience), ρ.
- is an increasing function of the price of cereals at the lean season, $\overline{p}$.
- does not depend on the utility function, u. Hence, it does not depend on risk aversion.
- does not depend on the price of cereals at the harvest season, $\underline{p}$.

2.2 Price and harvest uncertainty

Assume that, at the time of the harvest season, the price of cereals in the lean season is unknown. It is distributed according to cumulative distribution H. At the time of the lean season, future harvest is also not perfectly known. We assume that the harvest is γf, where γ is distributed according to cumulative distribution G.

At the harvest season of year t, the harvest $\gamma f(x_{t-1})$ is known. The farmer chooses s_t that maximizes:

$$U_t = \sum_{d=t}^{+\infty} \rho^{\frac{d-t}{2}} u\left(\underline{p}\left(\gamma f\left(x_{d-1}\right) - s_d\right)\right) + \rho^{\frac{d-t+1}{2}} \int u\left(p s_d - b x_d\right) dH(p)$$

The first order condition is given by:

$$\underline{p} u'\left(\underline{p}\left(\gamma f\left(x_{d-1}\right) - s_d\right)\right) = \sqrt{\rho} \int p u'\left(p s_d - b x_d\right) dH(p)$$

At the lean season of year t, the price is known, it is p. The farmer chooses x_t that maximizes:

$$U_t = \sum_{d=t}^{+\infty} \rho^{\frac{d-t}{2}} u\left(p s_d - b x_d\right) + \rho^{\frac{d-t+1}{2}} \int u\left(\underline{p}\left(\gamma f\left(x_d\right) - s_{d+1}\right)\right) dG(\gamma)$$

The first order condition is given by:

$$b u'\left(p s_t - b x_t\right) = \sqrt{\rho}\, \underline{p} f'\left(x_t\right) \int \gamma u'\left(\underline{p}\left(\gamma f\left(x_t\right) - s_{t+1}\right)\right) dG(\gamma)$$

The two first order conditions can be rewritten as follows:

$$\underline{p}\int\gamma u'\left(\underline{p}\left(\gamma f\left(x_{t-1}\right)-s_t\right)\right)dG\left(\gamma\right)=E\left(\gamma\right)\sqrt{\rho}\int pu'\left(ps_t-bx_t\right)dH\left(p\right),$$

and,

$$b\int pu'\left(ps_t-bx_t\right)dH\left(p\right)=E\left(p\right)\sqrt{\rho}\underline{p}f'\left(x_t\right)\int\gamma u'\left(\underline{p}\left(\gamma f\left(x_t\right)-s_{t+1}\right)\right)dG\left(\gamma\right)$$

or,

$$\frac{\underline{p}}{E\left(\gamma\right)\sqrt{\rho}}=\frac{\int pu'\left(ps_t-bx_t\right)dH\left(p\right)}{\int\gamma u'\left(\underline{p}\left(\gamma f\left(x_{t-1}\right)-s_t\right)\right)dG\left(\gamma\right)},$$

and,

$$f'\left(x_{t-1}\right)=\frac{b}{E\left(p\right)\sqrt{\rho}\underline{p}}\frac{\int pu'\left(ps_t-bx_t\right)dH\left(p\right)}{\int\gamma u'\left(\underline{p}\left(\gamma f\left(x_t\right)-s_{t+1}\right)\right)dG\left(\gamma\right)}$$

Let us focus on the stationary solution. The stationary quantity of fertilizer is given

$$x=f'^{-1}\left(\frac{b}{E\left(\gamma\right)E\left(p\right)\rho}\right),$$

for all t.

The quantity of fertilizers:

- is a decreasing function of the price of fertilizers, b.
- is an increasing function of the annual discount factor (patience), ρ.
- is an increasing function of the expected price of cereals at the lean season, $E\left(p\right)$.
- is an increasing function of the expected "yield", $E\left(\gamma\right)$.
- does not depend on the utility function, u. Hence, it does not depend on risk aversion.
- does not depend on the price of cereals at the harvest season, $\underline{p}$.

3 Experimental and Survey Design

The survey design generated a representative sample of farmers in two administrative districts of Burkina Faso, Tuy and Mouhoun provinces. Those provinces are located in the west region of the country, which is the main maize production area. Data were collected in January 2013 in cooperation with the Confédération Paysanne du Faso (CPF), a nation-wide farmers' organization. A total number of 77 villages were randomly selected from the CPF list. In those villages, an average number of 20 households were randomly selected as well. With the help of the Burkinabe Agriculture Ministry, twenty investigators and two supervisors were recruited. A total number of 1549 farmers were surveyed between January 21, 2013 and February 7, 2013. Surveys were conducted in Dioula language. The survey included an experimental section aimed at eliciting risk and time preferences and a household survey part aimed at characterizing households and farming decisions. The total survey lasted around one hour per farmer. We interviewed the household head, defined as the person responsible for farming decisions.

3.1 Household survey

The household survey was made of nine distinct sections: (i) socio-economic characteristics of the household and of the household's head; (ii) household's economic assets; (iii) crop production; (iv) crop sales; (v) fertilizer expenses: (vi) non agricultural activities undertaken by the household members; (vii) household's social expenses; (viii) household's loans and (ix) household's food expenses. The summary statistics at the household level are presented in Table 1. On average, surveyed households have 13 members, 7 being working with farming activities. In our sample, 30% of households are equipped with latrines and with sheet metal roof in 70% of cases. Households hold an average of 5 bikes, 1 motorbike and 2 heads of draft cattle. In the majority of the cases, the household is headed by a man, who is 43 years old on average, has received a written education in 40% of cases and is very often member of a farmer organization (85% of cases), whatsoever CPF or another organization.

In the regions were surveys were conducted, main crops are cotton, maize, sorghum, millet and sesame. Millet and sorghum are traditionally consumed, while maize and sesame are sold as well. This is reflected in the average sown areas and in the production levels in the sample (Table 1). Average yields are of 1.1 ton per ha for cotton, 1.5 ton per ha for maize and respectively 0.8 and 0.7 per ha for sorghum and millet. The difference in cereal yields is likely to result from different fertilizer uses. Many farmers indeed use fertilizer for maize production, which is not the case for other cereals. The average quantity of fertilizer used for maize production - 238 kg per ha - hides a quite high heterogeneity among sampled farmers, as quarter of the sample does not use any

Table 1: Sample characteristics

Household's characteristics	unit	Obs.	mean	std. dev.
family size	number	1549	12.7	8.8
labor force	number	1549	7.1	5.4
latrine	yes=1, no=0	1549	0.32	0.46
roof quality	yes=1, no=0	1549	0.69	0.46
bike	number	1549	4.9	4.2
motorbike	number	1549	0.95	1.13
draft cattle	number	1549	2.4	2.54
sex	yes=male	1549	0.98	0.13
age	years	1549	42.9	12.7
education	yes=1, no=0	1549	0.39	0.49
producer organization	yes=1, no=0	1549	0.85	0.35
Cultivated areas				
cotton	ha	1549	3.95	4.61
maize	ha	1549	2.06	3.28
sorghum	ha	1549	1.84	2.2
millet	ha	1549	0.89	1.55
sesame	ha	1549	0.5	1.07
Production levels				
cotton	kg	1543	4454	10867
maize	kg	1545	3624	7100
sorghum	kg	1546	1340	1953
millet	kg	1547	544	1002
sesame	kg	1540	105	262
Yield levels				
cotton	kg per ha	1218	1145	2145
maize	kg per ha	1273	1543	1269
sorghum	kg per ha	1212	819	1529
millet	kg per ha	796	700	1077
sesame	kg per ha	600	239	323

fertilizer for maize production.

The fertilizers used by the sampled farmers come from various sources, most farmers using fertilizers they receive from the firm that buys their cotton production, the cotton marketing board. In Burkina Faso, cotton is indeed a vertically integrated sector, where producers are ensured to sell their production at the end of the season and to receive fertilizers at the beginning of the season. The amount of fertilizers they receive is linked to the cotton surface they declare to cultivate. Fertilizer costs are deducted from the price they receive at the end of the season. The maize sector is much less integrated and maize producers do not have a specific mechanism to facilitate them fertilizer access, although there are stores in the area. In the absence of such a fertilizer delivery scheme, farmers strategy tend to be the diversion of part of the cotton fertilizer package that they receive from the marketing board, in order to apply fertilizer in their maize fields. This is a risky strategy, as cotton yields are likely to be lower and this may in turn arouse suspicion from the marketing board. Thus we expect that more risk adverse farmers will not fully follow this strategy. We take this into account in our empirical estimations.

3.2 Eliciting Risk and Time Preferences

In order to elicit farmers' risk and time preferences, we use an artefactual field experiment in the terminology of Harrison and List (2004). We asked hypothetical risk aversion and time discounting questions. The experiment offered farmers lotteries of risky and safe options to elicit their risk aversion and sets of choices between present and future consumption options to elicit their discount factor. If most field experiments have been led in developed countries (Harrison, Lau, and Williams, 2002; Andersen, Harrison, Lau, and Rutstrom, 2008), the use of experiments in developing countries has recently received a great deal of attention (Cardenas and Carpenter, 2008; Duflo, 2006; Harrison, Lau, and Williams, 2002). Contributions include experiments in Ethiopia, India and Uganda (Humphrey and Verschoor, 2004), in Zimbabwe (Barr and Genicot, 2008) and in Vietnam (Tanaka, Camerer, and Nguyen, 2010). Harrison, Lau, and Williams (2002) elicit individual discount rates from a nationally representative sample of 268 Danish people. Using a sample of 253 Danish people as well, Andersen, Harrison, Lau, and Rutstrom (2008) make a joint elicitation of both discount rates and risk aversion coefficients, such approach providing lower estimates of discount rates compared to previous studies. Focusing on developing countries, Harrison, Humphrey, and Verschoor (2010) use data collected from risky choice experiments in Ethiopia, India and Uganda. Tanaka, Camerer, and Nguyen (2010) collect data from sample of 160 Vietnamese villagers and show that people living in wealthy villages are not only less risk averse but also more patient.

3.2.1 Risk aversion

Our experiments were built on the risk aversion experiments of Holt and Laury (2002). We used a multiple price list design to measure individual risk preferences. We ran two experiments offering successively low and high payoffs. In each experiment, each participant was presented a choice between two lotteries of risky and safe options, and this choice was repeated nine times with different pairs of lotteries, as illustrated in Table 2 in the case of low pay-offs. Farmers were asked to choose either lottery A or lottery B at each game (a game is a row in the table). The first row of Table 2 indicates that lottery A offers a 10% probability of receiving 1000 FCFA and a 90% probability of receiving 800 FCFA, while lottery B offers a 10% probability of a 1925 FCFA payoff and a 90% probability of 50 FCFA payoff.

Low payoffs were chosen because they fitted previous experiments of Holt and Laury (2002) and Andersen, Harrison, Lau, and Rutstrom (2008) and because they amount to approximately one day income for a non skilled worker in Burkina Faso (around 1000 FCFA a day, ie 2 USD a day). In the second experiment, farmers were asked to choose between lotteries with 10 times higher payoffs. The offered payoffs were corresponding to an important amount of money, 10000 FCFA (around 20 USD) corresponding to the average price of one bag of 100 kg cereal after harvest or to 10 days income for a non skilled worker.

In practice, lotteries A and B were materialized by two bags containing 10 balls of different colors (green for 1000 FCFA, blue for 800 FCFA, black for 1920 FCFA and transparent for 50 FCFA). The composition of the bags was revealed to the farmers but they had to choose between picking a ball in bag A or bag B without seeing the balls (blind draw). As indicated in last column of Table 2, neutral risk adverse individuals (r around zero) are expected to switch from lottery A to lottery B at row 5, while risk loving individuals ($r < 0$) are expected to switch to lottery B before row 5 and risk adverse individuals ($r > 0$) are expected to switch to lottery B after row 5.

Table 2: The paired lottery-choice decisions with low payoffs

	lottery A				lottery B					
	prob 1	gain 1	prob 2	gain 2	prob 3	gain 3	prob 4	gain 4	range of r	
1	0.1	1000	0.9	800	0.1	1925	0.9	50	$-\infty$	-1.71
2	0.2	1000	0.8	800	0.2	1925	0.8	50	-1.71	-0.95
3	0.3	1000	0.7	800	0.3	1925	0.7	50	-0.95	-0.49
4	0.4	1000	0.6	800	0.4	1925	0.6	50	-0.49	-0.14
5	0.5	1000	0.5	800	0.5	1925	0.5	50	-0.14	0.15
6	0.6	1000	0.4	800	0.6	1925	0.4	50	0.15	0.41
7	0.7	1000	0.3	800	0.7	1925	0.3	50	0.41	0.68
8	0.8	1000	0.2	800	0.8	1925	0.2	50	0.68	0.97
9	0.9	1000	0.1	800	0.9	1925	0.1	50	0.97	1.37
10	1	1000	0	800	1	1925	0	50	1.37	$+\infty$

Note: Last column was not shown to respondents.

Since all lottery choices are in the gain domain, we assume a utility function of the following form:

$$U(x) = x^{1-r}/(1-r)$$

where x is the lottery prize and r is the parameter to be estimated and denotes risk aversion. Expected utility is the probability weighted utility of each outcome in each row. A farmer is indifferent between lottery A (probability p_A to earn a ; probability $1-p_A$ to earn b) and lottery B (probability p_B to earn c and probability $1-p_B$ to earn d), if and only if his expected utility is the same in both lotteries:

$$p_A.U(a) + (1-p_A).U(b) = p_B.U(c) + (1-p_B).U(d)$$

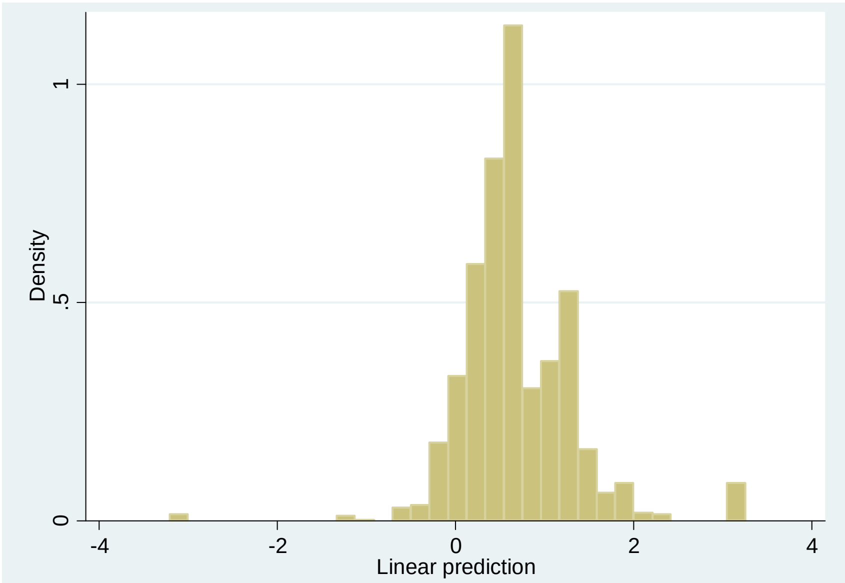
Assuming a CRRA (Constant relative Risk Aversion) utility function,

$$p_A.\frac{a^{1-r}}{1-r} + (1-p_A)\frac{b^{1-r}}{1-r} = p_B.\frac{c^{1-r}}{1-r} + (1-p_B)\frac{d^{1-r}}{1-r}$$

which can be solved numerically in term of r.

Just as in Holt and Laury (2002) and Andersen, Harrison, Lau, and Rutstrom (2008), we allow risk aversion to be a linear function of the observed households' characteristics. We consider six characteristics that we assumed unambiguously exogenous in driving risk preferences: gender, age, family size, education, village, province. Estimated individual r coefficients are predicted values of the model, which we estimate using an interval regression (tobit model). Figure1 displays the distribution of the risk coefficients predicted from the low-payoff experiment. Results show that a minority of farmers exhibit a risk loving or risk neutrality behavior. Most of the farmers are risk adverse, with an average of $r = 0.69$ in the low-payoff experiment and $r = 0.63$ in the high-payoff experiment. This is in line with previous findings suggesting that farmers' preference for risk is quite low (Binswanger and Sillers, 1983). Those average values are comparable to the ones obtained by Harrison, Humphrey, and Verschoor (2010) for India, Ethiopia and Uganda using similar experiments.

Figure 1: Estimated risk aversion coefficients (low payoffs)



3.2.2 Discount Rate

To our knowledge, there is no study that aim to elicit discount rates in developing countries. We thus built our time preference experiment on works of Harrison, Lau, and Williams (2002) and of Coller and Williams (1999). However we had to adapt the content in order to present pay-offs that make sense to the respondents. To do so, we ran pre-tests of the experiment from a subset of farmers before the survey. We used two experiments to elicit farmers' time preferences, those experiments differing in the time delays offered to the farmers. In the first experiment, farmers were invited to choose between receiving a given amount in one day time (option A) or receiving a bigger amount in five-days time (option B), and this choice had been repeated nine times, with different payoffs. The amount of payment A corresponds to the average price of one bag of 100 kg

Table 3: "Would you prefer to get A in one day or B in five days?"

	A	B	range of δ (4 days)	
1	10000	10400	0	0.016
2	10000	10700	0.016	0.027
3	10000	11000	0.027	0.039
4	10000	11500	0.039	0.057
5	10000	12000	0.057	0.076
6	10000	13000	0.076	0.111
7	10000	14000	0.111	0.144
8	10000	17000	0.144	0.236
9	10000	20000	0.236	0.320

Note: Range of δ indicates the associated interval for monthly δ for a respondent who switches from A to B.

of cereals after harvest. Table 3 displays the experiment aiming to elicit this discount rate that we call current discount rate hereafter. The first row of Table 3 indicates that farmer had to choose between receiving 10,000 FCFA tomorrow or 10,400 FCFA in five days.

In a second experiment, farmers were invited to choose between receiving a given amount in one month-time (option A) or receiving a bigger amount in two-months time (option B), and this choice being repeated eight times, with different payoffs. Table 4 displays the experiment aiming to elicit this discount rate that we call future discount rate hereafter.

An agent is indifferent between receiving payment M_t at time t or payment M_{t+1} at time $t+1$ if and only if:

$$U(w+M_t) + \frac{1}{1+\delta}U(w) = U(w) + \frac{1}{1+\delta}U(w+M_{t+1})$$

where w is his background consumption and δ accounts for the discount rate which is the parameter to be estimated. Assuming again a CRRA utility function and assuming no background consumption, this writes:

$$\frac{M_t^{1-r}}{1-r} = \frac{1}{1+\delta}\frac{M_{t+1}^{1-r}}{1-r},$$

Table 4: "Would you prefer to get A in one month or B in two months?"

	A	B	range of δ	
1	10000	12000	0	0.06
2	10000	15000	0.06	0.13
3	10000	18000	0.13	0.19
4	10000	20000	0.19	0.23
5	10000	23000	0.23	0.28
6	10000	29000	0.28	0.38
7	10000	48000	0.38	0.60
8	10000	75000	0.60	0.83

Note: Range of δ indicates the associated interval for monthly δ for a respondent who switches from A to B.

from which we get δ as a function of risk aversion r:

$$\delta = \left[\frac{M_{t+1}}{M_t}\right]^{1-r} - 1$$

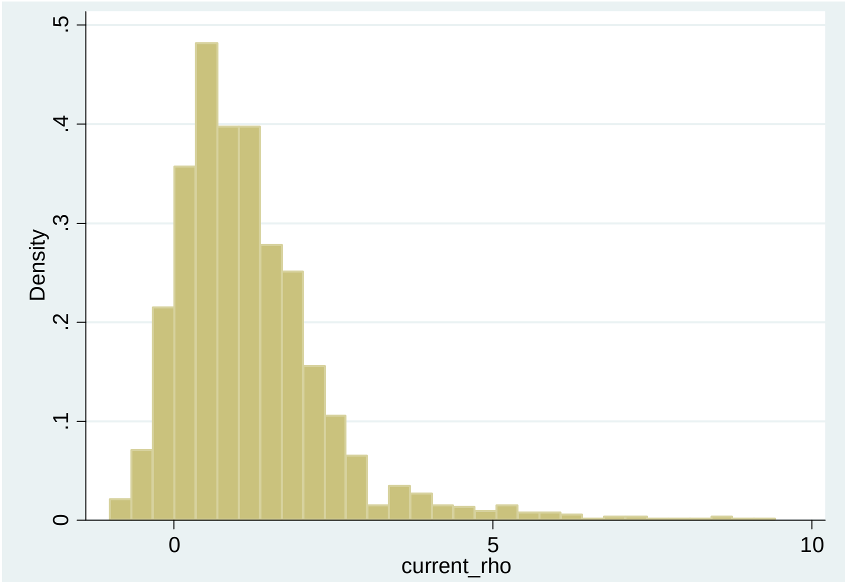
Here again we allow δ to be a linear function of exogenous covariates. Estimated individual δ coefficients are predicted values of the model that we also use in order to elicit individual r, which we estimate again using an interval regression. Figure2 displays the estimated current discount rates.

4 Elicited Impatience and Observed Fertilizer Use

We now aim to estimate the fertilizer demand in accordance with the theoretical model presented in Section 2. In the empirical model, the quantity of fertilizer used is a variable which measures the total quantity of plant nutrients used. Fertilizer products includes nitrogenous, potash, phosphate, and urea. Nitrogenous, potash and phosphate elements are applied together with the use of NPK bags. Urea is applied separately. We thus estimate separately the demand for NPK and the demand for urea. The farmer's impatience is measured by δ and risk aversion is measured by r. We moreover control for prices by adding dummies for municipalities.[2] We proxy household capital through the number of bovines and plows, and labor force is measured through the number of people

[2]Municipalities are administrative areas that are larger than villages and smaller than provinces, and that we believe relevant to catch spatial price variability in the studied area.

Figure 2: Estimated current discount rates



in the family who work in farm activities. Finally, we control for the fact that farmers may produce cotton and for the fact that farmers may have a specific access to credit to finance fertilizers, in order to take into account that some farmers have facilitated access to fertilizer through the cotton marketing board or through credit:

$$y_i = \beta_0 + \beta_1 \delta_i + \beta_1 r_i + \beta_3 X_i + \epsilon_i$$

where $\epsilon_i \sim N(0, \sigma_\epsilon)$ and X includes control variables.

We argue that no selection bias problem can arise in this framework because farmers who use fertilizer for maize production differ from farmers who do not in characteristics that are observable to us. Applying OLS to the empirical model thus yields unbiased estimates of βs. Results on NPK and urea use are presented in the following subsections. Overall, results show that risk aversion does not affect fertilizer use, which is in line with the theoretical model; and that discounting does significantly decrease fertilizer use.

4.1 Time discounting and npk use

Results on the effect of risk and time preferences on NPK use are presented below. Four specifications are presented, according to the variables used for risk aversion (r elicited with low or high payoffs) and for discounting (δ elicited for present choices or future

Table 5: Descriptive Statistics for sample used in the regression

Variable	Mean	Std. Dev.	Min.	Max.	Unit
Qty of fertilizer	286.1	463.1	0	5800	kg per ha
cattle size	8.4	18.8	0	443	nb
plows	0.86	0.64	0	4	nb
workers	7.6	5.5	1	45	nb
total area	10.9	9.2	.12	88.5	ha
cotton area	4.4	4.8	0	45	ha
r (low payoffs)	0.72	0.64	-3.2	3.25	none
r (high payoffs)	0.66	0.73	-3.06	4.14	none
δ (future choices)	.21	.25	-.6	1.03	none
δ (present choices)	.17	.16	-.88	.8	none

Note: δ (future choices) are monthly values. δ (present choices) have been computed as monthly values for sake of comparison.

choices).

If we consider the two proxies used for household capital, we find that the number of cattle held by the household has no significant effect on the application of npk fertilizer while the number of plows has a positive effect on the use of npk fertilizer on maize production. This indicates that cattle breeding and maize intensification are not necessarily complementarity activities and that applying more npk fertilizer goes with having more plows which is somehow intuitive. Similarly, the number of workers has a positive effect on the used of npk, indicating that labor intensification is compatible with chemical intensification. The fact to produce cotton has a positive effect on npk use, this effect being explained that when producing cotton farmers receive fertilizers packages and that they may use part of those fertilizers to apply within their maize plots. Surprisingly, credit access has no significant effect on npk used : this reflects that the most common strategy to ensure npk access is to deflect part of the chemical packages they receive from cotton marketing boards. Risk aversion has no significant effect on npk use in 3 of the 4 specifications, which is consistent with what was predicted by the model. Impatience has a negative effect on npk use : the more impatient are farmers, the less they apply npk in their maize plots. This effect of time discounting is consistent with what was expected by the model and is robust to all the empirical specifications we have been testing. The size of the time discounting coefficient is higher when considering future choices than present choices, but this is compensated by the fact that discount rates vary in a ratio of 1 to 5 for present choices (the mean being 1.11) and future choices (the mean being 0.21).

Table 6: Time discounting and NPK use-OLS estimates

	[1]		[2]		[3]		[4]
cattle size	4.040245		4.004037		4.027191		3.992887
	(1.28)		*(1.28)*		*(1.28)*		*(1.28)*
plows	73.2563	***	73.21261	***	73.65294	***	73.59564
	(4.33)		*(4.37)*		*(4.36)*		*(4.40)*
workers	19.8997	***	19.41755	***	20.0509	***	19.59882
	(3.63)		*(3.51)*		*(3.63)*		*(3.52)*
cotton producer	79.91614	*	80.54533	*	83.37103	*	83.86923
	(1.86)		*(1.88)*		*(1.92)*		*(1.93)*
credit access	-13.92188		-19.05117		-14.73758		-19.84113
	(-0.31)		*(-0.41)*		*(-0.32)*		*(-0.42)*
r	41.519		41.90424	*	27.91937		28.80172
	(1.52)		*(1.81)*		*(1.16)*		*(1.33)*
δ	-29.92941	**	-160.1178	***	-28.60701	**	-154.9424
	(-2.20)		*(-2.93)*		*(-2.04)*		*(-2.58)*
constant	-137.1421		-153.4081		-127.6782		-143.5267
	(-1.57)		*(-2.07)*		*(-1.50)*		*(-1.95)*
communal dummies	Yes		yes		yes		yes
payoffs (r)	low		low		high		high
time frame (δ)	present		future		present		future
obs	1271		1271		1271		1271

4.2 Time discounting and urea use

Results on the effect of risk and time preferences on urea use are presented below. Just as it was the case for NPK estimations, four specifications are presented, according to the variables used for risk aversion (r elicited with low or high payoffs) and for discounting (δ elicited for present choices or future choices).

Table 7: Time discounting and urea use-OLS estimates

	[1]		[2]		[3]		[4]	
cattle size	1.260921		1.244226		1.255213		1.239174	
	(1.20)		*(1.20)*		*(1.20)*		*(1.20)*	
plows	33.22543	***	33.15072	***	33.4136	***	33.33568	***
	(4.19)		*(4.21)*		*(4.15)*		*(4.18)*	
workers	10.6995	***	10.48062	***	10.79783	***	10.59765	***
	(4.86)		*(4.68)*		*(4.88)*		*(4.71)*	
cotton producer	35.59481	*	35.4664	*	37.27554	**	37.13041	**
	(1.93)		*(1.92)*		*(2.01)*		*(2.01)*	
credit access	2.824796		-.2753378		2.278924		-.8887407	
	(0.14)		(-0.01)		(0.11)		(-0.04)	
r	22.28626	*	23.46025	*	16.12034		17.48495	*
	(1.67)		*(1.95)*		*(1.55)*		*(1.82)*	
delta	-13.8006	**	-81.88903	**	-13.35164	**	-80.53556	**
	(-2.09)		*(-2.23)*		*(-2.10)*		*(-2.21)*	
constant	-63.6481		-70.38646		-59.64403		-66.34171	
	(-1.40)		*(-1.75)*		*(-1.40)*		*(-1.76)*	
communal dummies	yes		yes		yes		yes	
payoffs (r)	low		low		high		high	
time frame (delta)	present		future		present		future	
obs	1271		1271		1271		1271	

The obtained results are very much similar with the ones obtained for NPK use. Impatience negatively affects urea application, this effect being robust to the different specifications. However, we find that risk aversion increases urea use in 3 of the 4 specifications (see Table **??**).

4.3 Hyperbolic discounting and npk use

In this subsection we investigate the role of hyperbolic discounting on fertilizer use. Some farmers may be more impatient about present choices than future choices and may present present biased preferences. Similarly, farmers may be more impatient about future choices than present choices and in this case may have future biased preferences. To empirically assess the influence of time inconsistencies we compare farmers' answers regarding present choices and future choices. We interpret their choices as being present biased if the inferred current discount rate is larger than the future discount rate. We further distinguish between individuals with 'weakly present biased preferences' and 'extremely present biased preferences' just as in Bauer, Chytilova, and Morduch (2012). Weakly present biased preferences are represented one cell below the diagonal in Table 8, while extremely present biased preferences are represented in the lower left cells of Table 8. Similarly, we interpret choices as being future biased if the inferred future discount rate is higher than the current discount rate : those choices are represented in the upper right cells of Table 8.

Table 8: Distribution of discount rates inferred from responses to time preferences questions

			Future discount rate				
			Patient			Impatient	
			0<d<0.3	0.3<d<0.48	0.48<d<1.1	d>1.1	Total
Current discount rate	Patient	0<d<0.3	574	20	9	20	623
			37%	1%	1%	1%	40%
		0.3<d<0.48	45	6	1	0	52
			3%	0%	0%	0%	3%
		0.48<d<1.1	140	60	4	4	208
			9%	4%	0%	0%	13%
	Impatient	d>1.1	151	102	68	345	666
			10%	7%	4%	22%	43%
		Total	910	188	82	369	1549
			59%	12%	5%	24%	100%

The distribution of current and future discount rates establishes that 25 per cent of the answers correspond to extremely present biased preferences and that 11 per cent correspond to weakly present biased preferences. In contrast, only 3 per cent of the received answers are from farmers who are more patient now than in the future. Roughly one third of the sampling has present biased preferences while future biased preferences are rather unusual: these proportions are similar to those found by Bauer, Chytilova, and Morduch (2012) in India, by Ashraf, Karlan, and Yin (2006) in the Philippines and by Meier and Sprenger (2010) in the United States.

The influence of time inconsistent preferences on NPK fertilizer use is empirically tested, after controlling for household capital, labor, access to NPK fertilizer, risk aversion, impatience and price levels (see Table 9).

Table 9: Time inconsistent preferences and NPK use

	[1]		[2]		[3]		[4]	
cattle size	*4.072672*		*4.040756*		4.061305		4.031114	
	(1.30)		*(1.30)*		(1.30)		(1.30)	
plows	73.21115	***	73.19685	***	*73.56761*	***	*73.54026*	***
	(4.35)		(4.40)		*(4.38)*		*(4.43)*	
workers	*19.91563*	***	*19.45313*	***	20.05229	***	19.62461	***
	(3.64)		*(3.53)*		(3.63)		(3.53)	
cotton producer	78.03802	*	77.99829	*	*81.2194*	*	*81.10226*	*
	(1.84)		(1.84)		*(1.90)*		*(1.89)*	
credit access	*-15.7315*		*-21.41572*		-16.49976		-22.18664	
	(-0.36)		*(-0.47)*		(-0.37)		(-0.49)	
r	38.11211		39.25514	*	*25.3343*		*26.89579*	
	(1.41)		(1.71)		*(1.07)*		*(1.26)*	
delta	*-28.55765*	**	*-160.4902*	***	-27.27192	**	-155.5166	***
	(-2.15)		*(-2.99)*		(-2.00)		(-2.66)	
strong present bias	-56.68419	**	-59.69779	**	*-58.02057*	**	*-60.9123*	**
	(-2.25)		(-2.34)		*(-2.32)*		*(-2.41)*	
weak present bias	*-34.80298*		*-34.75081*		-34.96375		-34.76312	
	(-1.07)		*(-1.06)*		(-1.10)		(-1.08)	
future bias	-2.446388		9.7621		*-4.369148*		*7.274019*	
	(-0.05)		(0.22)		*(-0.10)*		(0.16)	
constant	-109.7794		-123.7685		-100.199		-113.8408	
	(-1.22)		(-1.64)		(-1.15)		(-1.53)	
communal dummies	yes		yes		yes		yes	
payoffs (r)	low		low		high		*high*	
time frame (delta)	present		future		present		future	
obs	1271		1271		1271		1271	

We find that farmers having extremely present biased preferences are less likely to use NPK in their maize plots. This effect is robust to the four empirical specifications led, and is additional to the effect of impatience that is still highly significant.

5 Conclusion

The textbook model of optimal fertilizer consumption choice tells that impatience decreases fertilizer use. Standard practice in inter-temporal welfare analyses is to assume that time preferences are the same across farmers when one would expect a priori that subjective time preferences differ across different individuals. In this paper we elicit discount rates for individuals. Taking into account individual financial constraints and access to fertilizer for maize production, we moreover show that experimental choices correlate with observed fertilizer use behavior. This result is in line with prediction of the textbook model of optimal fertilizer consumption choice made by farmers.

This paper presents one of the the first field evidence that links hypothetical time discount questions to observed agricultural decisions. It contributes to the economic literature in several ways. First, we focus on fertilizer use for crop production, while previous studies have focused on saving products. Second, contrary to Ashraf, Karlan, and Yin (2006) and Dupas and Robinson (2013) who study the impact of individual preferences on the participation to a development program, we rather study current agricultural behavior of farmers. Third, contrary to studies that focus on self-discipline problems that farmers may face when they make farming decisions, we provide evidence that discounting can explain variability in fertilizer use. We argue that even in cases when farmers are not financially constrained and benefit from facilitated access to fertilizer, we can establish a causal link between the discount rate and fertilizer use. This result stands in a framework where farmers are time-consistent as in a framework where farmers have present biased preferences.

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